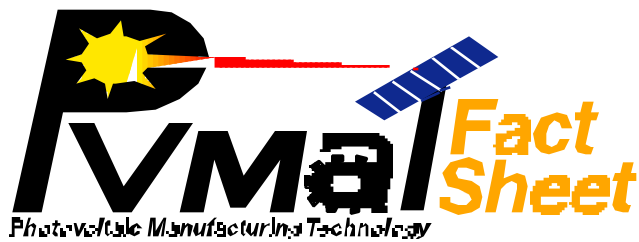


Full-Scale Testing of Modules Prepared with Experimental EVA-Based Encapsulants

Highlights

- Six module manufacturers used four new encapsulants without significant problems
- Found consistently high levels of curing of experimental encapsulants in these modules
- Observed no failures related to encapsulant material during qualification testing, except for yellowing of one experimental formulation

This Springborn Testing and Research, Inc. project is part of the 1992 solicitation of PVMaT—a cost-shared partnership between the U.S. Department of Energy and the nation's PV industry to improve the worldwide competitiveness of U.S. commercial PV manufacturing.



Springborn Testing and Research, Inc.

Goal

The goal of Springborn Testing and Research, Inc. (STR) under the 1992 solicitation of PVMaT was to improve ethylene vinyl acetate (EVA) technology. Specific objectives were to:

- develop a “family” of stable, reformulated EVA encapsulants that may be adapted to various module constructions
- * demonstrate the functional adequacy of these encapsulants under end-use conditions and in qualification tests using full-size modules.

Background

EVA encapsulants are used extensively by module manufacturers to bond and protect the structures that comprise PV modules. Since 1981, EVA encapsulants have proven dependable during production, module fabrication, and end-use. Despite widespread acceptance of A9918P and similar formulations for PV, some module producers and end-users have reported cases of yellowing or browning of field-aged modules under conditions of high temperatures and intense sunlight.

Although isolated, these reports raised concerns about the long-term reliability of EVA encapsulants, and hence, about the long-term, reliable performance of the modules protected by the encapsulants. For this project, STR researched the problem, designed reformulated, experimental encapsulants, and tested both experimental and standard encapsulants to determine reliability.

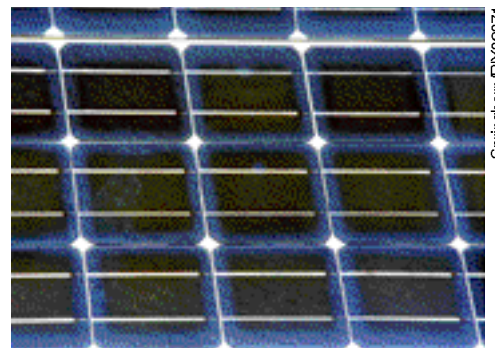
Technical Approach

STR approached the project in three stages. In the first stage, the company defined the problem through a literature search, field survey, and accelerated UV-aging studies (AAS) to evaluate the influence of compositional, processing, and operating parameters

on A9918P discoloration. STR also used instrumental analysis to verify suspected chemical mechanisms of degradation.

In the second stage, STR developed approaches, including reformulating systems, for stabilizing the EVA encapsulant against discoloration and degradation. These “stabilization strategies” were evaluated by AAS and were periodically checked for browning with measurements of the Yellowness Index (ASTM D1925). This work resulted in four experimental EVA-based encapsulants—three “standard cure” (X9903P, X9923P, and X9933P) and one “fast cure” (X15303P)—which demonstrated greatly reduced discoloration on AAS.

During the final stage, STR tested the functional adequacy of these experimental encapsulants by subjecting them to various analyses and comparing the results with a control encapsulant (the standard A9918P formulation).



Modules showing degradation.

To test the encapsulants, STR supplied PVMaT team members—ASE Americas, AstroPower, EBARA Solar, Photocomm, Siemens Solar Industries, Solec International, Solarex, and United Solar Systems Corp.—with 0.018-inch-thick sheets of the experimental EVA encapsulant material. Using their normal materials for constructing superstrates, interconnects, and backing, team members prepared two types of modules: full-size, 50-W modules, and

mini-modules (2.5 in. x 2.75 in. and 2.5 in. x 5.5 in.). The modules were subjected to different tests.

Full-Size Modules were subjected to qualification testing per IEEE Standard 1262 and to field testing.

Qualification testing involves a set of procedures whereby the modules are subjected to extreme conditions—such as damp heat, high humidity, thermal cycling, and ultraviolet radiation. Modules are analyzed to determine if they perform up to standards—electrically, mechanically, and optically—under those conditions.

For this test, most of the manufacturers supplied Arizona State University's Center for Energy Systems Research (ASU/CESR) with 18 modules—six each of modules representing three of the four possible experimental encapsulants. In all, ASU/CESR tested 102 modules.

For field testing, manufacturers supplied ASU/CESR with 36 modules. Each participating manufacturer provided six to eight modules—two each of modules representing three or four of the experimental encapsulants, plus the conventional “fast cure.” All modules had superstrates that used low-iron glass containing cerium oxide.

Modules were installed for ASU/CESR on a two-axis tracker by Arizona Public Service in Tempe. The modules were fitted with fixed resistive loads so that each would operate within +10% of its peak power point—to represent a typical March day, which is near the mean annual temperature. For measuring operating temperature, a thermocouple was installed on the back of each module.

ASU periodically measured current-voltage characteristics (short-circuit current, open-circuit voltage, maximum power, and fill factor) under two operating conditions: maximum power and short circuit. Data were collected under actual test conditions and translated to standard conditions. ASU also made infrared thermal maps of each module at peak power and short-circuit conditions.

Mini-Modules were subjected to accelerated aging. For this, each mini-module was provided with leads through the backing material and was connected to a 1-ohm resistor. The back of each mini-module was insulated with a layer of Mylar, and the assembly was mounted in a sample holder.

Samples were placed in a xenon-arc Weather-Ometer and exposed to 2 suns at 90°C and >95% relative humidity for 6 months.

One team member prepared mini-modules with Tefzel cover film, and each team member prepared one set of mini-modules with cerium-oxide-containing glass. Otherwise, all mini-modules used non-cerium, low-iron glass to provide “worst case” conditions.

Results

Qualification Testing

During 1000 hours of damp heat, X9933P encapsulants turned bright yellow. This was the only encapsulant-related yellowing.

The experimental encapsulants also exhibited a consistently high level of curing. Autopsy work following testing showed average gel contents of greater than 83%, versus a typical 80% for conventional EVA-based grades.

Also, there was little or no loss of adhesion to cells, interconnects, or glass. However, under damp-heat conditions, some backing film laminates showed a loss of adhesion to the encapsulant and developed a brown discoloration that was traced to the adhesive layer.

Field Testing

Some short-circuited modules exhibited hot-spot heating: one hot cell reached 86.6°C, and nine other modules had “hot” cells that ranged from 70.1° to 78.3°C. With a resistive load, these cells operated at about 65°C.

Accelerated Aging

After 26 weeks of exposure, most A9918P-encapsulated controls using low-iron glass superstrate turned brown over the cells, similar to that seen in the stage-one survey of modules in the field. Except for samples made with X9933P, all mini-modules prepared with experimental grades, as well as with 15295P and cerium-oxide-containing glass, showed no browning over the cells.

One surprise was browning of three experimental encapsulants under the Tefzel cover film. But because there is available oxygen in these systems, STR analysts suspect that a different browning mechanism is taking place than under glass superstrates. The experimental encapsulants are promising for modules with glass superstrates; but for Tefzel cover film, the preferred encapsulant is conventional A9918P or 15295P.

Company Profile

Springborn Testing and Research, Inc. is now known as Specialized Technology Resources, Inc. (STR). STR provides services to more than 6000 sponsors worldwide. These services include high-quality contract materials research, development, and engineering; specialty manufacturing of polymeric materials and components, including PV encapsulants; testing and inspecting for the qualification of materials; and quality assurance testing of electrical components, textiles, and apparel.

References

Holley, W.H.; Agro, S.; Galica, J.; Thoma, L.; White, R.; Yorgensen, R. Annual Report, NREL Subcontract No. ZAG-3-11219-02-105661 (Nov 1994).

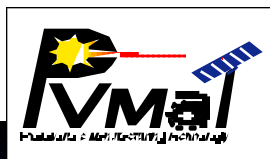
Holley, W.H. Annual Report, NREL Subcontract No. ZAG-3-11219-02-105661 (Jan. 1996).

Ezrin, M.; et al., “Discoloration of EVA Encapsulant in Photovoltaic (Modules),” *Preprints, SPE Annual Tech. Conf.*, Boston, MA, (May 1995) pp. 3957–3960.

Ezrin, M.; et al., “Further Studies of Discoloration of EVA Encapsulant in Photovoltaic Modules,” *Preprints, SPE Annual Tech. Conf.*, Indianapolis, IN, (May 1996), pp. 3260–3264.

Holley Jr., W.H.; et al., “Advanced Development of Non-Discoloring EVA-Based PV Encapsulants,” *AIP Conf. Proc. No. 353, 13th NREL PV Program Review*, H. Ullal and C.E. Witt, ed., AIP Press, NY (1995), pp. 636–642.

Holley Jr., W.H.; et al., “UV Stability and Module Testing of Non-Browning Experimental PV Encapsulants,” *25th IEEE PV Specialist Conf.*, Washington, D.C. (May 1996).



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